Observations on Processes of Assessment and Concerns about the Teaching of Analytical Thinking

Judith Puncochar,* School of Education, Leadership, and Professional Service
Northern Michigan University, USA

Don Faust, Department of Mathematics and Computer Science
Northern Michigan University, USA

Abstract

Honing students' analytical thinking skills could expose the uncertainty of our current knowledge and ambiguity of contexts in which university instructors teach. Four instructional strategies were posited to improve university teaching for analytical thinking: (1) implementation of three to five seconds of wait time, (2) providing students with practice for honing skills of observation and asking questions, (3) assessment of analytical thinking with instructor feedback, and (4) use of logic fundamentals in university teaching. Implementing logic fundamentals could increase the likelihood that students use analytical thinking to explore strengths and limitations of arguments ubiquitous throughout their personal, professional, and civic lives. Expanding the New Version of Bloom's Taxonomy to include "Critical Thinking" and "Problem Solving" within the level of "Creating" is suggested to differentiate analytical thinking at the level of "Analyzing" as foundational to critical thinking at the level of "Creating".

Keywords: assessment, pedagogical philosophy, critical thinking, analytical thinking

*Corresponding author. Email: jpuncoch@nmu.edu

Introduction

Observations on the importance of critical thinking in a university education might do well to address new ideas about the assessment and teaching of analytical thinking. Much attention is paid to the need for universities to find ways to build critical thinking skills in students for their personal and professional lives. Current political climates across the globe and in the United States make a clear case for clear analytical thinking in students' citizenship lives as well.

Universities often start their efforts to improve students' critical thinking skills with initiatives undertaken "across the curriculum" through general education courses. While such efforts are important, we focus this paper on teaching the fundamentals of analytical thinking independent of curriculum. We also attend to assessment of analytical thinking in student learning, which has a place in outcomes assessment of academic programs and institutional-level learning.

Teaching Fundamentals of Analytical Thinking

What, then, are some teaching fundamentals for analytical thinking? Seven high-impact teaching practices have been identified as good practice in undergraduate education (Chickering & Gamson, 1987), as follows:

1. Encourages contact between students and faculty
2. Develops reciprocity and cooperation among students
3. Encourages active learning
4. Gives prompt feedback
5. Emphasizes time on task

6. Communicates high expectations
7. Respects diverse talents and ways of learning

Teaching students to think analytically or critically does not appear specifically on the Chickering & Gamson (1987) list, even though critical thinking is a frequent Student Learning Outcome (SLO) for academic programs in the United States and is rated second in importance only to SLOs related to knowledge of content (Grandinetti & Puncochar, 2019; Peñaloza & Puncochar, 2019; Puncochar, Barch, Albrecht, & Klett, 2018). "Encourages active learning" (Chickering & Gamson, 1987) could incorporate teaching analytical or critical thinking skills. University instructors sometimes use critical thinking in a description of their teaching (Janssen et al., 2019). Examples of how to teach critical thinking usually include presenting a problem, question, or text for "analysis" followed by "a detailed description" of the student's understanding (i.e., assuming appropriate wait time of three seconds; see Rowe, 1974, 1978).

Differentiating between Analytical Thinking and Critical Thinking

Analysis is a detailed examination of the elements or structure of an issue. Critical thinking is the objective analysis and evaluation of an issue to form a judgment. An objective analysis precedes a critical evaluation; accordingly, analytical thinking precedes critical thinking. Skills for analytical thinking and critical thinking differ (Anderson & Krathwohl, 2001; Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). The terms have merged in some research literature as critical-analytical thinking (Brown, Afflerbach, & Croninger, 2014). Occasionally, "problem solving" is included in critical-analytical thinking (Johnson, 2017).

An analysis of these terms leads to a refinement of their referents wherein analytical thinking becomes the basis of critical thinking and problem solving.

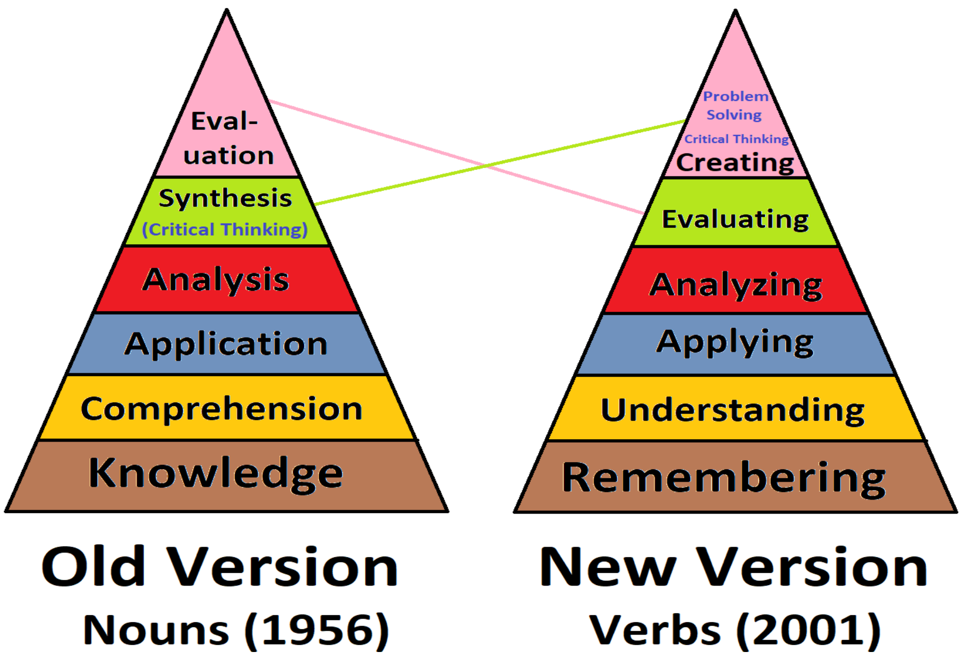

Figure 1. Bloom's Taxonomy (1956) describes a hierarchical model to classify educational learning objectives into levels of increasing cognitive complexity. The New Bloom's Taxonomy (2001) uses verbs instead of nouns and places "Creating" above Evaluating. We place "Critical Thinking" and "Problem Solving" above Analysis in the Old Version and above Analyzing in the New Version of Bloom's Taxonomy.

In both the old and new versions of Bloom's Taxonomies, analytical thinking is foundational to critical thinking. Critical thinking is the ability to evaluate the importance of the objective analysis and ask the right questions. Critical thinking is not merely describing one's observations, which is at the two lower levels of Bloom's Taxonomies (i.e., Knowledge/Remembering and Comprehension/Understanding). In 2014, Oceans of Data gathered experts from science, education, business, and law enforcement to describe specific skills and knowledge needed to compete in a big-data-centered economy. Analytical thinking ranked highest in both the knowledge AND skills (see Figure 2). The results were validated by almost 100 data-analyst peers (see Krumhansl, 2016). Although analytical thinking ranked higher than critical thinking in both knowledge and skills, we posit that analytical thinking is a necessary precursor to critical thinking and problem solving.

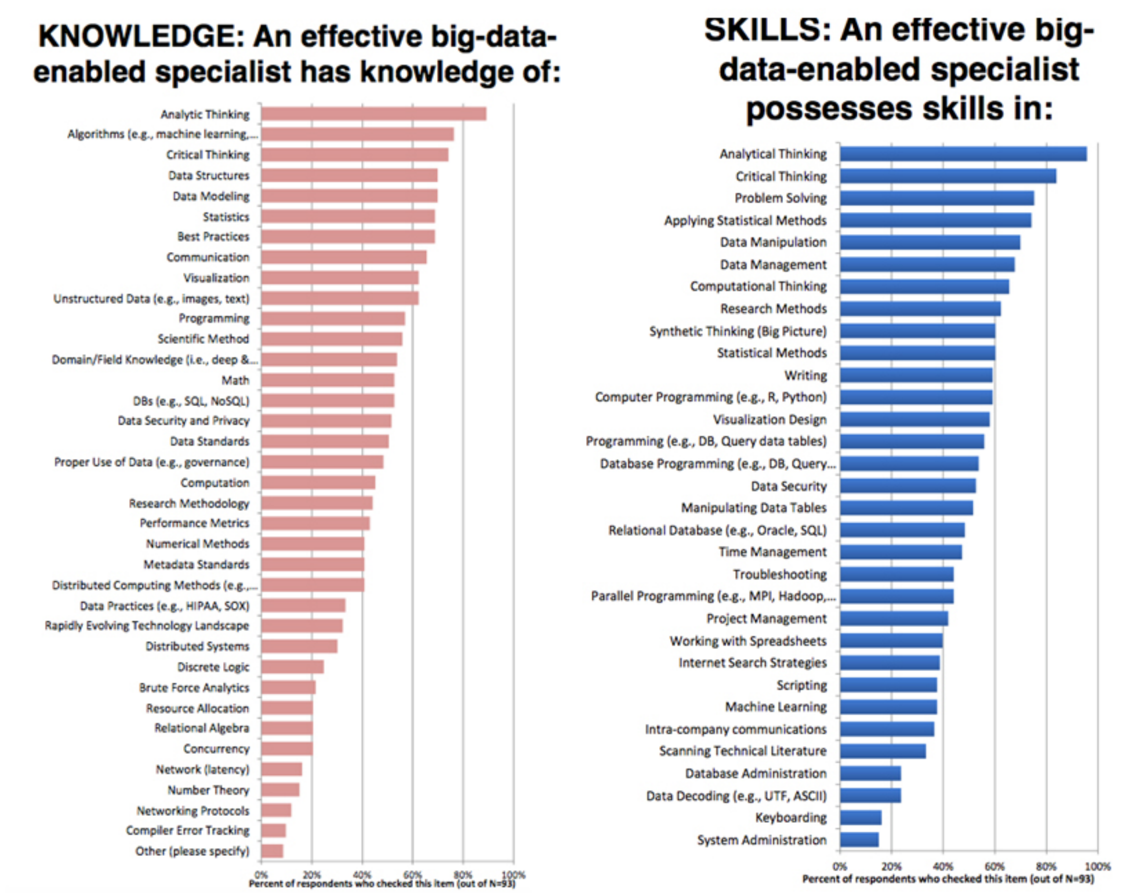

Figure 2. An expert panel at an Oceans of Data 2014 conference developed a list of knowledge and skills necessary to work with large data sets (see Krumhansl, 2016).

Teaching for Analytical Thinking

University instructors who strive to hone their students' use of analytical thinking tend to practice three teaching strategies. First, they allow their students sufficient wait time—

approximately three seconds (see Rowe, 1974; 1978)—before answering the question or asking another student for a response (Bianchini, 2008). Second, they provide students considerable analytical thinking practice. Third, they provide students with a framework to assess analytical thinking. We will take up each strategy in turn.

Wait Time. The concept of wait-time has demonstrated substantial effects to improve inquiry instruction (Bianchini, 2008). Upon asking a question, most instructors wait on average only about 1 to 1.5 seconds for a response before answering the question themselves or positing a follow-up question. Waiting three to five seconds had substantial effects on the level of student participation and quality of student responses (Rowe, 1974, 1978). The increase in time could allow students enough time to analyze the question and formulate a response or muster enough confidence to share their response aloud.

Practice. Analytical thinking is *not* a description of how one understands an issue, problem, or text. Students begin to demonstrate analytical thinking by breaking down a problem, articulating the boundaries and variables of the problem, and exploring contextual considerations (e.g., ethical considerations) (Krumhansl, 2016). Providing opportunities to hone observation skills could help students articulate a detailed examination of the elements or structure of an issue. The use of active teaching strategies could allow students an opportunity to practice asking questions and could promote modeling of analytical thinking through guided or collaborative practice (see Robb, 2015) or "What if" questions (Tauber & Mester, 1994).

Assessing Analytical Thinking. Instructor involvement in the assessment of student learning is an assumed practice of many universities (e.g., see HLC Assumed Practices, 2019; Higher Learning Commission Policy Book, 2019, p. 30). A possible general framework for assessment of analytical thinking has four processes: (1) identification of a Student Learning Outcome for analytical thinking, (2) description of measures used to collect analytical thinking learning data (e.g., rubrics); (3) analysis of results; and (4) actions taken to use results to improve student learning. This proposed model is similar to Assessment Report templates used by several universities (e.g., Northern Michigan University's 2019 Assessment of Learning Report Form, available from the authors).

A word of caution on creating a learning outcome for analytical thinking. Learning outcomes describe essential knowledge, skills, and attitudes required by students to demonstrate an observable use of the skill. Instructors occasionally conflate the Means of Assessment with the Student Learning Outcome. For example, passing a mathematical examination or a thesis exam is not a Student Learning Outcome. The examination is the assessment measure or Means of Assessment. The learning is what students know or how students explain or analyze an issue, problem, or text, usually at a targeted level of attainment on an appropriate measure of analytical thinking. The assessment focus of analytical thinking is on the knowledge or skills of student learning, not on the means used to measure the learning.

An assessment framework rarely includes the types of measures to use. Instructors usually determine measures of analytical thinking, which typically rely on end-of-course examinations or standardized tests of students' presumed last skills-acquired proficiencies. For example, science instructors might use a lab or capstone assignment to collect student assessment data related to analytical thinking, and mathematics instructors might use final exam questions. When students do *not* meet proficiency or advanced rates expected on analytical thinking measures, actions taken usually include changes to the examinations, curriculum, or student support services, rather than changes to instructional strategies.

Rubrics to assess analytical thinking (e.g., to analyze information) sometimes include additional assessment criteria for skills related to applying, communicating, evaluating, and integrating information (e.g., see Azid, Maksin, Mohktar, & Hashim, 2015). Rubrics with an exclusive focus on analytical thinking could include skills of examining evidence systematically, identifying patterns, making logical extrapolations from the evidence, and identifying limitations of conclusions. Ratings could vary (e.g., excellent, proficient, incomplete, or absent). However, the use of rubrics to assess formative gains and provide feedback to diagnose students' strengths and weaknesses in analytical thinking is still infrequent (Brown, Afflerbach, & Croninger, 2014, p. 559).

Fundamentals of Analytical Thinking

Some confusion continues to exist over how to teach analytical thinking fundamentals. Here we clarify the fundamentals of what analytical thinking IS NOT and IS. Analytical thinking IS NOT simply the traditional logical trivialities of classical logic such as asserting that all sentences are TRUE or FALSE, or insisting that students learn two-valued truth-tables for logical operators AND, OR, and NOT. In addition, analytical thinking IS NOT fundamentally fostered by trivial homework assignments such as analyses of social media or newspapers. Analytical thinking IS engendered by learning about the construction and use of tools for the representation and processing of our evolving knowledge about our world. Such deeper learning, we conjecture, creates measurable improvement in analytical skills.

Let us now turn to a brief description of three components of such deeper learning, namely, (1) Goedel's Completeness Theorem, (2) epistemological considerations regarding the uncertainty of our knowledge, and (3) the logics of evidence. First, a crisp delineation of *semantics* (tools for the representation of meaning) and *syntax* (tools for the representation of linguistic descriptions) leads to a framework for describing possibly the most important theorem of 20^{th} century logic, namely, the Completeness Theorem of Kurt Goedel. This theorem asserts that, in any formally described first-order theory, a sentence is true in all models of the theory if and only if the sentence is provable in the theory. As an example, consider any theory of active learning: Any sentence in that theory is provable within that theory if and only if that sentence is true in all models (implementations) of that active learning theory. An example of such a sentence is "Social Skills training is required." This sentence is provable in any active learning theory, and hence this sentence is true in all implementations of any active learning theory.

Second, epistemology (the study of what we know and how we come to know it) helps us to understand that (so far) all our knowledge seems to involve uncertainty. We thereby need to become more humble in our assertions and therefore more able to understand that *our view* may well be incomplete. Ernst Mach, a seminal forerunner of the Vienna Circle (along with Albert Einstein, Bertrand Russell, and others), wrote on page 2 of "*The Analysis of Sensations*" (1897):

> "Colors, sounds, temperatures, and so forth are connected to one another in manifold ways, and with them are associated dispositions of mind, feelings, and volitions. Out of this fabric, that which is relatively more fixed … stands prominently forth, engraves itself on the memory, and expresses itself in

> language. Relatively greater permanency is exhibited … by certain complexes … which therefore receive names and are called bodies. Absolutely permanent such complexes are not."

These "labelings," as described by Mach (1897), are both helpful and unhelpful to our incomplete view. Such "fuzzy labelings" are helpful for the "rough and ready" ways in which we collect partial and fuzzy data, quickly make our decisions, and jump to action. Yet, these "fuzzy labelings" are unhelpful in that we too often develop an unjustified assurance as to the precision and clarity of our knowledge.

Significant improvements in our discourse, as well as in our strivings to generate widely acceptable problem solutions, may flow from a deeper understanding of the current uncertainty of our knowledge. Vagueness of our knowledge, if not heeded sufficiently, often leads to overconfidence regarding our knowledge (see Puncochar & Fox, 2004). We recommend for further reading Bertrand Russell's wonderful essay "Vagueness" (Russell, 1923) and for further detail Russell's 1948 book *Human Knowledge*: *Its Scope and Limits*.

Finally, the clarity of Goedel's Completeness Theorem about logical formalisms, combined with the lack of clarity of our knowledge of the world, leads to a felt need for logics that go beyond the inadequacies of Classical Logic. Such logics attempt to be crisp in their formalisms while at the same time providing tools for representing and processing uncertain evidential knowledge. Evidence Logic (Faust, 2000) is an example of such a logic, providing for gradational levels of confirmatory and refutatory evidence. (See also Crossley [1972] for an overview of the basics of mathematical logic.)

Conclusion

We seek to expand current understanding of a context within which university instructors could explore improvements of teaching for learning through analytical thinking. First, we suggest using the New Version of Bloom's Taxonomy and expanding the category of "Creating" to include "Critical Thinking" and "Problem Solving." Second, we encourage the use of four instructional strategies to improve university teaching of analytical thinking: (1) implement three to five seconds of wait time, (2) provide students with practice for honing skills of observation and asking questions, (3) assess analytical thinking with instructor feedback, and (4) use logic fundamentals in university teaching. Third, we posit that the goals of increasing awareness of and broadening understanding about logic fundamentals and their utility could increase the likelihood that students use analytical thinking to explore strengths and limitations of arguments ubiquitous throughout their personal, professional, and civic lives.

References

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives*. Boston, MA: Allyn & Bacon (Pearson Education Group).

Azid, N., Maksin, M., Mohktar, A., & Hashim, R. (2015). Effectiveness of learning activities using interactive modules successful intelligence. *Australian Journal of Basic and Applied Sciences, 9*(32), 1-9. Retrieved from www.ajbasweb.com

Bianchini, J. A. (2008). Mary Budd Rowe: A storyteller of science. *Cultural Studies of Science Education*, 3, 799-810. Retrieved from http://dx.doi.org/10.1007/s11422-008-9132-y

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals: Handbook I: Cognitive Domain.* New York, NY: Longmans, Green and Co.

Brown, N., Afflerbach, P., & Croninger, R. (2014). Assessment of critical-analytic thinking. *Educational Psychology Review, 26*(4), 543-560. Retrieved from http://www.jstor.org.nmu.idm.oclc.org/stable/43548442

Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *AAHE Bulletin, 39*(7), 3-7.

Johnson, A. P. (2000). *Up and out: Using creative and critical thinking skills to enhance learning*. Boston, MA: Allyn and Bacon.

Crossley, J. N. et al. (1972). *What is mathematical logic?* New York, NY: Oxford University Press.

Faust, D. (2000). The concept of evidence. *International Journal of Intelligent Systems,* 15, 477–493. http://dx.doi.org/10.1002/(SICI)1098-111X(200006)15:6%3C477::AID-INT1%3E 3.0.CO;2-B

Grandinetti, F. C., & Puncochar, J. (April 9-12, 2019). *Engaging our institutions in student learning assessment*. Higher Learning Commission 2019 Annual Conference: Roadmaps for Student Success. Chicago, IL.

Higher Learning Commission (2019). HLC Assumed Practices (CRRT.B.10.020). Retrieved from https://www.hlcommission.org/Policies/assumed-practices.html?highlight=WyJhc3N1bWVkIiwicHJhY3RpY2VzIiwiYXNzdW1lZCBwcmFjdGljZXMiXQ

Higher Learning Commission (2019). HLC Policy Book. Retrieved from *download.hlcommission.org/policy/HLCPolicyBook_POL.pdf*

Janssen, E. M., Meulendijks, W., Mainhard, T., Verkoeijen, P. J. L., Heijltjes, A. E. G., van Peppen, L. M., & van Gog, T. (2019). Identifying characteristics associated with higher education teachers' Cognitive Reflection Test performance and their attitudes towards teaching critical thinking. *Teaching and Teacher Education, 84*, 139-149. Retrieved from https://doi.org/10.1016/j.tate.2019.05.008

Johnson, B. (2017). Teaching students to dig deeper, 2nd edition. Routledge, New York: New York. http://dx.doi.org/10.4324/9781315165653

Krumhansl, C. (2016). Analytical thinking in the workplace and the classroom. Retrieved from http://oceansofdata.org/analytical-thinking-workplace-and-classroom

Mach, E. (1897). *The analysis of sensations.* Dover Edition, 1959; Translation: by C. M. Williams and Sydney Waterlow.

Peñaloza, F., & Puncochar, J. (April 9-12, 2019). *Assessment Planning – Special Interest Group*. Higher Learning Commission 2019 Annual Conference: Roadmaps for Student Success

Puncochar, J., Barch, J., Albrecht, B., & Klett, M. (October 19, 2018). *Outcomes assessment of co-curricular and student support services.* Lilly 2018 Conference on College & University Teaching, Traverse City, MI.

Puncochar, J., & Fox, P. W. (2004). Confidence in individual and group decision-making: When 'Two Heads" are worse than one, *Journal of Educational Psychology*, *96,* 582–591. http://dx.doi.org/10.1037/0022-0663.96.3.582

Robb, L. (2015). Strategies to improve students' analytical thinking. Retrieved from http://edublog.scholastic.com/post/strategies-improve-students-analytical-thinking#

Rowe, M. B. (1974). Wait time: Slowing down may be a way of speeding up. *American Educator, 11*, 38-43, 47. Retrieved from http://dx.doi.org/10.1177/002248718603700110

Rowe, M. B. (1978). Wait, wait, wait.... *School Science and Math, 78*, 207–216. Retrieved from http://dx.doi.org/10.1111/j.1949-8594.1978.tb09348.x

Russell, B. (1923). "Vagueness", *Australasian Journal of Philosophy and Psychology, 1*(2), 84-92. Retrieved from http://dx.doi.org/10.1080/00048402308540623

Russell, B. (1948). *Human Knowledge*: *Its Scope and Limits.* New York, NY: Simon and Schuster.

Tauber, R. T., & Mester, C. S. (1994). *Acting lessons for teachers: Using performance skills in the classroom*. Westport, CN: Praeger.